MASSACHUSETTS INTERFAITH POWER & LIGHT **SUCCESS STORIES**

In Depth Case Study: Boston Synagogue, Boston MA

A view from the front of Boston Synagogue with the new Heat Pump

Boston Synagogue (also known as Charles River Park Synagogue) is a small, lay-led synagogue located in the heart of the Old West End near Massachusetts General Hospital. The building was constructed in 1971. It is a single-story structure, with a dramatic pitched "skylight" roof over the Sanctuary. The exterior and much of the interior has architectural block walls. The interior spaces include a Sanctuary with linked Social Hall, office wing, large lobby, restrooms and a kitchen. A small basement provides space for mechanical equipment. The synagogue, which is used year round, had been using the original air conditioning and heating until 2008.

INITIAL CONDITIONS

Air Ducts in the Sanctuary

Air Ducts in Basement

Manual Thermostats of old system

Before the changes, the synagogue used ***steam heat*** that was imported from Trigen. (See appendix for details on Trigen heating). The synagogue uses no oil or gas. Domestic hot water is heated by electricity. Stoves are electric. The heating system was located in the basement and dispersed heat throughout the building through air ducts. The treated air was pushed through the air ducts by a large fan system in the basement. (See picture above) For many years the system worked reasonably well, but there were problems that burdened the synagogue. The building took a very long time to heat and cool, primarily because both systems needed to travel through the basement and go through large air ducts to reach the sanctuary. Because the synagogue had manual thermostats, the lag-time required that someone be at the facility about an hour ahead of time to turn up the thermostat so that the building would be comfortable for a service or meeting. Non-programmable thermostats result in a superfluous amount of energy use, as people will often turn them up too high or forget to turn them down. This had been costing the synagogue money.

The old air conditioning roof top system, linked to the basement compressor.

The original 30-ton ***air conditioning*** system had two units on the roof that provided conditioned air produced by a compressor in the basement. A fan would blow air through the same ducts that were used for steam-generated heat. The system was functioning, but it was at the end of its useful life. Repairs were frequent and very costly. The air conditioner was leaking refrigerants so it required annual recharges. The total cost of repairs for the air conditioning from July 2006 to June 2007 was $10,453; from July 2007 to June 2008 it was $5,275.

It was clear action would need to be taken soon, but upgrading to a new system would require a very large upfront payment for which the synagogue did not have the money at the time. Because the system could function with routine albeit not inexpensive repairs, the board believed it would be easier to keep the same system for the time being.

All this changed in June, 2008 when the air conditioning system completely gave out. Boston Synagogue called their air conditioning maintenance firm, that fortunately had its own professional engineers, to have a look and investigate the options. According to the engineers, repairing the old system was not worth it at this point because replacing the broken parts of the old one would cost more than purchasing an entirely new system. Also, the leaking fluid contained CFC's (Chlorofluorocarbons) that were harmful to Earth's ozone layer. The decision was made not to repair the system.

The heat of summer forced the synagogue to purchase makeshift portable air conditioning unit. The portable unit was enough to keep small rooms comfortable, but it was not effective in cooling large areas such as the sanctuary and the social hall.

Portable Air Conditioning Unit

CHANGE

At this point, it was obvious to members of the synagogue's board that a good, long-term investment in cooling was needed. The MIP&L *Environmental Stewardship Assessment* report from 2004 had recommended a high efficiency air conditioning unit. The synagogue decided to investigate. The AC maintenance firm was asked for recommendations about potential air conditioning units. The recommended new cooling systems would cost about $100,000. Actions would include removal of the old compressor and fan from the basement and installation of new ones in their place. If the new systems were set up in the basement, then they would be able to run air through the existing air ducts. Unfortunately, the compressor in the basement was built into the structure of the synagogue during its construction; removal would be very costly. The cost proposed for the removal of the old system and installation of the new ones was equivalent to about one year's budget for all operations. The synagogue did not wish to take out such a large a loan. Instead they began to look for less expensive options that did not necessarily require the deconstruction of the old steam system.

During the summer of 2008, board members began to look into alternative options. An article in *The Boston Globe* about ductless systems presented the idea that it would be possible to bypass the need to go into the basement by installing a ductless system on the roof. Originally, board members thought the system operated like a single room air conditioner, and therefore would be inadequate to handle the synagogue's load requirement. However, in the process of doing the research, the synagogue president's son discovered that a vendor that was selling a multi-room system working off a single heat pump. (See Technical Appendix for details on system.) Potentially, this larger system could support the necessary HVAC load. More importantly, with a ductless system demolition costs could be avoided because the new system would not require space in the basement. As a result of this review, the synagogue asked their trusted air conditioning maintenance firm if it would be possible to install these new systems in their building and they asked whether they would be effective.

The company replied that a 15-ton system should keep the synagogue at a comfortable temperature except in extreme weather conditions, and that in most cases a 10-ton system would provide adequate cooling capacity. For heating, the full 15-ton system was recommended. Due to the ductless system's (a) lower aggregate tonnage compared to the old system, and (b) high efficiency variable speed compressor, the company suggested that the synagogue would realize substantial energy savings, paying back the initial capital cost of the system. Their provider also told them a synagogue in the North Shore had had ductless systems installed and that they were very happy with the results.

Based on this advice, and after looking at the North Shore synagogue's system in operation, the Boston Synagogue decided to proceed with the ductless system. It was done in two phases, to conserve funds. In Phase I, the synagogue board approved the installation of a 15-ton heat pump with 10 tons of air handler capacity (4 units at 2.5 tons each). It was believed that this would provide adequate capacity in most circumstances, and that the synagogue could rely on the old Trigen steam system on very cold winter days. Based on how this system worked in practice, the synagogue would consider a future Phase II installation of an additional 5 tons of air handler capacity, representing a 50% increase in HVAC capacity. This would enable the use of the full 15-ton heat pump capacity installed in Phase I, and hopefully reduce substantially the need for supplementary Trigen steam heat.

Heat Pump seen from Sanctuary

In late August 2008, the Phase I 15-ton heat pump was installed on top of the roof (pictured at left, and on page 1) and connected the four 2.5-ton systems that push out air cooled or heated by the pump.

There are two air handlers on each side of the sanctuary. (See photo at right). The congregation chose to install them on the sides of the sanctuary because they are close to where people usually sit, but not in a place where they will interfere with the synagogue's interior appearance.

Air Handlers in Sanctuary

In addition to installing a new heat pump, a **programmable thermostat** was installed to control the system. This installation solved many of the problems experienced with the manual thermostat, including time on-and-off. (See photo at left.)

EXPERIENCE TO DATE

The synagogue's initial experience with the Phase I system was that it provided excellent cooling during the August – September 2008 time horizon. The only issue was that on high-load days, the fan needed to be kept on high setting in order to provide adequate cooling at the rear of the sanctuary; this was addressed in Phase II by installing the two additional 2.5 ton air handlers in the rear. This also proved to be true during the summer of 2009.

With respect to heating: as anticipated, during the winter of 2008-2009, the synagogue need to continue to use costly steam from Trigen in addition to the heat received from the ductless systems to heat the building.

Based on this experience from the initial year of just using the 10 tons of capacity, the board decided in July 2009 to proceed with Phase II, in which two extra 2.5 ton units were installed near the back of the sanctuary. By having the additional 5 tons of heating power (which was installed in July 2009), the congregation believes that they will not have to rely on expensive Trigen steam for heating anymore, except on extremely cold days.

QUANTITATIVE OUTCOME

Water Heater

A review of data from the synagogue's last three fiscal years (August through July) yields several conclusions. First and most important, Boston Synagogue was able to reduce total energy use after making the switch. The average Btu use before the switch for both the air conditioning and steam heat was about 6.537×10^8 Btus per year. After the change, the synagogue has only used about 3.953×10^8 Btu's per year. This is about a 40% decrease. The higher number is actually higher because not all of those Btu's from steam make it to the synagogue, as some heat is lost on the way due to line loss. The synagogue has seen an increase in electricity consumption as it has come to rely more on the new systems. Before the summer of 2008, the synagogue averaged about 50,862 kwh a year. During the fiscal year of 2008-2009, the synagogue required 66,450 kwh. The average cost of electricity from 2006-2007 and 2007-2008 was $6,228. This cost jumped to $8,463 in the 2008-2009 fiscal year, about 35%.

The synagogue has witnessed a decrease in steam use as heat is now being provided by the new system. Before the summer of 2008, the synagogue averaged about 283 Mlb a year. During the fiscal year of 2008-2009, the synagogue required only 104 Mlb of steam. The average cost of steam from 2006-2007 and 2007-2008 was $9,506. This cost fell to $3,047 in the 2008-2009 fiscal year. This was nearly a 70% decrease. Steam use is expected to decrease even further during the coming year, with the additional 5 tons of capacity having been installed.

The average total cost for all HVAC systems in the 2006-2007 and 2007-2008 fiscal years was $15,735. ($23,731 if the costs of the repairs to the system are included). This dropped to $11,510 ($11,684 with repairs) in the fiscal year of 2008-2009. This is a 27% reduction. While these are already significant savings, when the unusually cold winter of 2008-2009 is taken into consideration in terms of degree days, the savings increase even more.[1] Adjusted for degree days of Aug 2008-Jul 2009 in comparison with the median of the past 14 years, the cost of running the HVAC systems for the 2008-2009 fiscal year was only $7,735. These figures influenced the board's conclusion that putting in the extra two systems should be enough to heat the building without the assistance of steam. If the synagogue is able to reduce its steam use to zero, a further saving roughly $3,000 a year would be realized, while experiencing a further increase of about $1,000 in electricity bills. (All 2009 $s.)

Although the reduction in carbon emissions was not as large as the reduction of energy bills, the synagogue did manage to reduce its emissions by a significant amount. Before the installation in the summer of 2008, the synagogue emitted about 184,000 pounds of CO_2 per year on average. During the fiscal year of 2008-2009, the synagogue only emitted about 147,756 pounds of CO_2 — a decrease of 20%. There are two main reasons that the reduction in pollution was not as great as the reduction in energy bills. The first reason is that the steam used to heat the synagogue is waste steam from a nearby electricity generating plant. As discussed in the Technical Appendix, co-generation is itself an efficient strategy, but in Boston the energy source for co-generation is mainly fossil fuel. The second point is that the electricity providers for the synagogue (as well as most of Massachusetts) rely on burning fossil fuels to generate electricity. As electricity produced from renewable sources begins to fill the grid, Boston Synagogue will experience a further reduction in carbon emissions.

TECHNICAL APPENDIX

Mitsubishi: The units installed are from Mitsubishi's PKFY series. These systems are lightweight and compact compared to most air systems of similar power. The Mitsubishi PKFY also has some of the lowest sound ratings in its class, so it is very quiet. This is particularly important because sound easily bounces off the concrete walls of the sanctuary. Maintenance is relatively easy as well. The filters on the wall can be easily removed, washed, or replaced and can be reached easily with a ladder. A key feature of the system is that it can both heat and cool. Thus, there is no need to install separate systems to heat and cool the building. Heat pumps also work efficiently, because they simply transfer heat, rather than burn fuel to create it. A heat pump has the capacity to do this because it uses an inverter-driven compressor. This compressor essentially allows the system to run the thermal process forwards or backwards. The process works by evaporating and condensing a refrigerant through a series of coils. When the refrigerant condenses it emits heat, and when it evaporates, it absorbs heat. An inverter-driven compressor can both condense and evaporate the refrigerant so that the coils can be cooled or heated. Also, the particular refrigerant used, R-410A, does not harm the ozone layer if leaked (although it is a greenhouse gas, so careful installation and maintenance is still required). The synagogue installed an air-source heat pump (takes air from above ground) rather than a ground-source (geothermal) because installation and repairs are far less expensive as excavation is not required.

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[1] For a discussion of Degree Days, and a means of tracking Utility Use & Cost, go to MIP&L's web site — **www.MIPandL.org** — and click on the Everyday Stewardship link. Then download the Utility Use & Cost *EES Brief*. Then go to Home or Congregation *Energy Use & Efficiency* links, and follow the directions to get an Excel form for tracking your home or congregation's utility use and cost AND to determine your carbon footprint.

Trigen: Trigen is the steam provider of Boston Synagogue. Its name comes from the term "trigeneration" which refers to the plant producing power, heat in the winter (through steam), and chilled water in the summer (by using hot steam to run an absorption process). The company exports steam to the synagogue from their nearby power plant on Kneeland Street. The imported steam heats up air that then circulates through the building. Although the power plant is very close to the synagogue, there is still some heat loss taking place as the steam travels through underground pipes, meaning not all of the heat produced makes it to the destination and efficiency drops. The Trigen billing process is complex. Like most energy companies, their billing system is tiered, so the less steam one uses, the more one pays per Mlb of steam. This is largely because transport and meter reading costs are independent of amount of steam used. Every bill should clearly state the cost per Mlb for each tier and how many Mlbs were used that month. As a smaller house of worship, Boston Synagogue suffers from this system. Also, there is a minimum fee of roughly $80 per month, so even if no steam is used, the synagogue is still charged. Unlike most energy companies, Trigen has to take manual readings of the steam used every month. This is not so bad if the meter is on the outside of the building. Unfortunately, Boston Synagogue's meter is on the inside of the building. If a representative from Trigen is unable to get inside the building for a meter reading, then the synagogue is charged based on the previous year's use and the average temperatures for the month. If no steam is used, but the representative is unable to set up an appointment, then the synagogue will be charged full price because Trigen cannot be sure when certain amounts of steam were used. This is a problem because the price of steam fluctuates. Now that the heat pump system has been installed, it becomes essential to provide Trigen with the means to monitor real time steam usage. Also, in order for the synagogue to officially discontinue use of steam for most of the year, Trigen must chain and lock the main steam valve in the basement of the building. These issues will be addressed during the coming year, and energy use and costs will continue to be monitored in order to validate the cost reductions and efficiency gains realized from installation and operation of the full 15 ton HVAC system.

Conversions:

1 kwh = 3,142 Btu

1 kwh = 1.2 lb CO_2 per year

1 Mlb Steam = 1,687,000 Btu

1 Mlb Steam = 129 lb CO_2 per year

This case study was prepared by Russell Foxworthy, August, 2009.

Boston Synagogue

Utility Use & Cost — 2006 to 2009

Data are for August of start year through July of following year.
New HVAC system used beginning FY 2008. Upgrade FY 2009.

ELECTRICITY

	2006	2007	2008
kWh	52,713	49,012	66,450
% of prior year		93.0%	135.6%
Cost	$6,341.45	$6,116.76	$8,463.11
Cost/kWh	$0.120	$0.125	$0.127
% of prior year		103.7%	102.1%
CO2 in lbs	63,256	58,814	79,740

STEAM

Mlb charged	281	285	156
Mlb used (est)	281	285	104
% of prior year		101.4%	36.5%
Cost	$9,320.67	$9,693.18	$3,047.46
Cost/Mlb used	$33.17	$34.01	$29.30
CO2 in lbs	122,516	124,260	68,016

per use estimate

REPAIR COSTS

	$8,503	$7,488	$173

DEGREE DAYS

Heating	3,108	3,133	4,292
% of prior year		100.8%	137.0%
Cooling	2,129	2,373	1,447
% of prior year		111.5%	61.0%

TOTAL

Utility Cost	$15,662.12	$15,809.94	$11,510.57
% of prior year		100.9%	72.8%
CO2	185,772	183,074	147,756
% of prior year		98.5%	80.7%
Degree Days	5,237	5,506	5,739
% of prior year		105.1%	104.2%